National Aeronautics and Space Administration

High End Computing Capability

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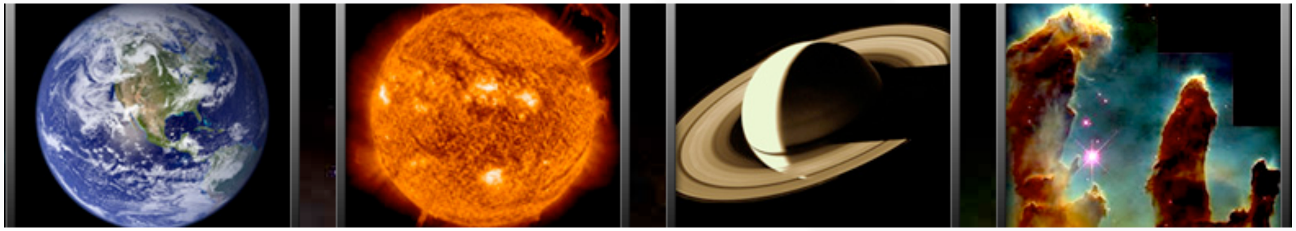
NASA Overview: Mission Directorates

- **Vision:** *To reach for new heights and reveal the unknown so that what we do and learn will benefit all humankind*
- **Mission:** *To pioneer the future in space exploration, scientific discovery, and aeronautics research*
- **Aeronautics Research (ARMD):** Pioneer and prove new flight technologies for safer, more secure, efficient, and environmentally friendly air transportation
- **Human Exploration and Operations (HEOMD):** Focus on ISS operations; and develop new spacecraft and other capabilities for affordable, sustainable human exploration beyond low Earth orbit
- **Science (SMD):** Explore the Earth, solar system, and universe beyond; chart best route for discovery; and reap the benefits of Earth and space exploration for society



Need for Advanced Computing

Enables modeling, simulation, and analysis (MS&A)

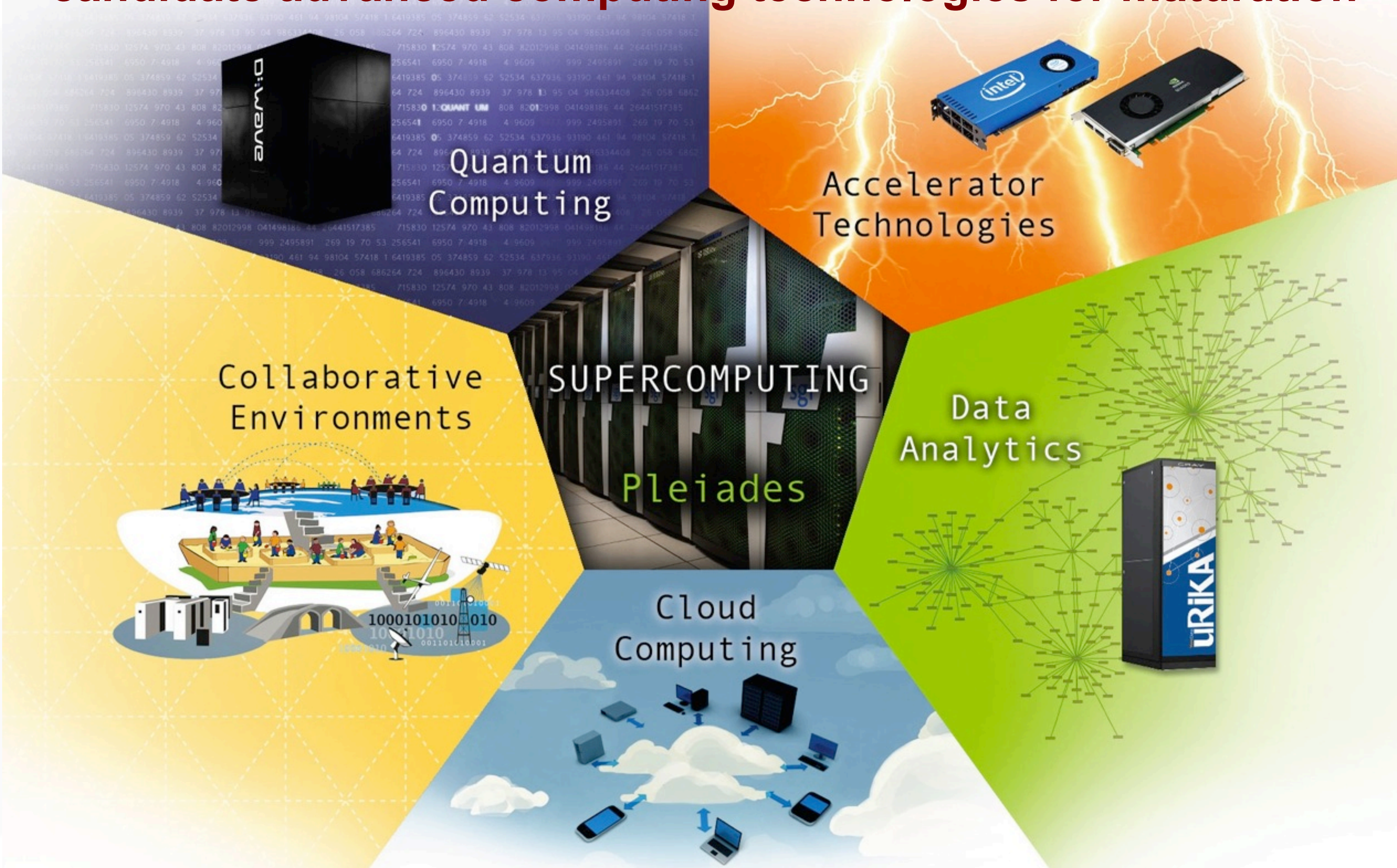
- Digital experiments and physical experiments are tradable
- Physical systems and live tests are generally expensive & dangerous (e.g., extreme environments), require long wait times, and offer limited sensor data


- Decades of exponentially advancing computing technology has enabled dramatic improvements in cost, speed, accuracy of MS&A – and provides predictive capability
- Numerous studies conclude that simulation is key to progress in science & engineering, and level of complexity is unattainable by strictly theoretical or experimental methods
- Aeronautics, Earth and Space Sciences, and Space Exploration all require orders-of-magnitude increase in MS&A capability to enhance accuracy, reduce cost, mitigate risk, accelerate R&D, and heighten impact

MS&A essential to rapidly and cost-effectively advance NASA goals

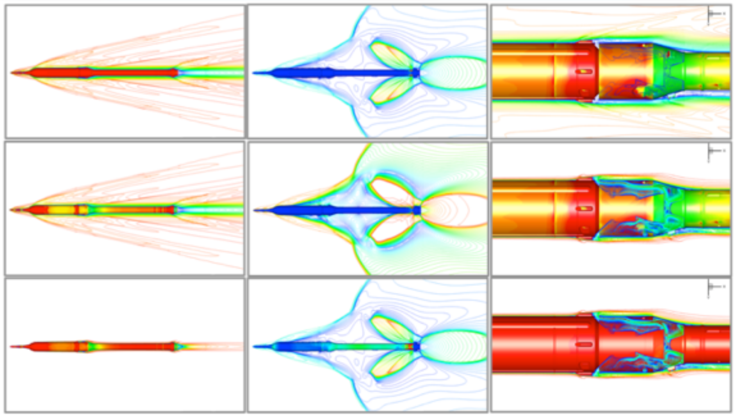
Advanced Computing Environment

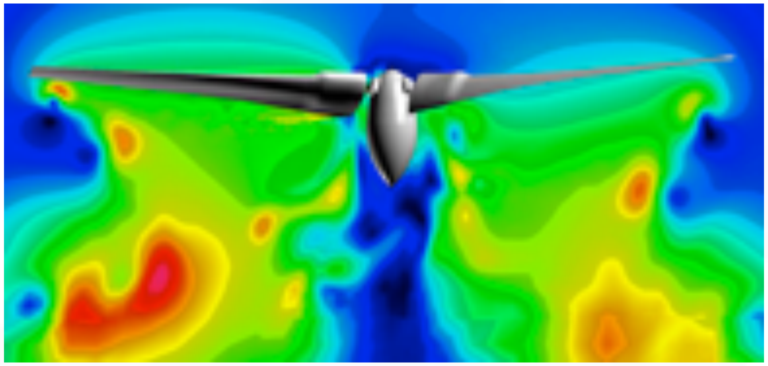
In addition to production supercomputing for NASA S&E applications, also researching, evaluating, and developing candidate advanced computing technologies for maturation

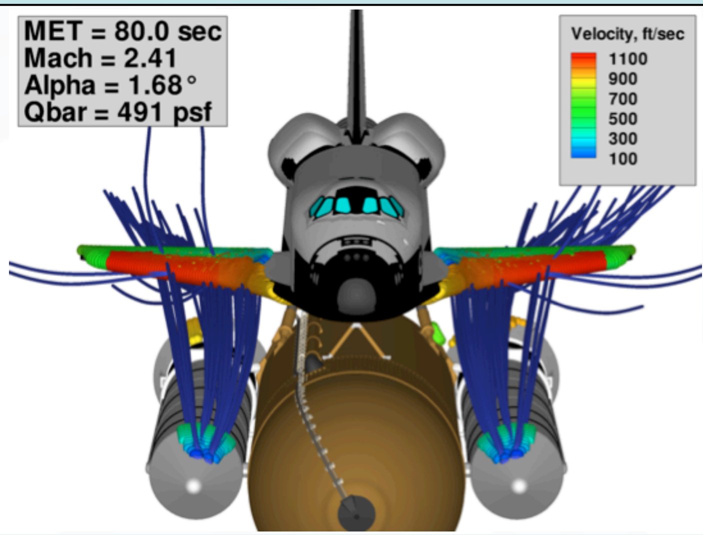


NASA's Diverse HPC Requirements

1) Engineering requires HEC resources that can handle large ensembles of moderate-scale computations to efficiently explore design space **(high throughput / capacity)**
2) Research requires HEC resources that can handle high-fidelity long-running large-scale computations to advance theoretical understanding **(leadership / capability)**


Aerodynamic database generation


Rotary wing aerodynamics

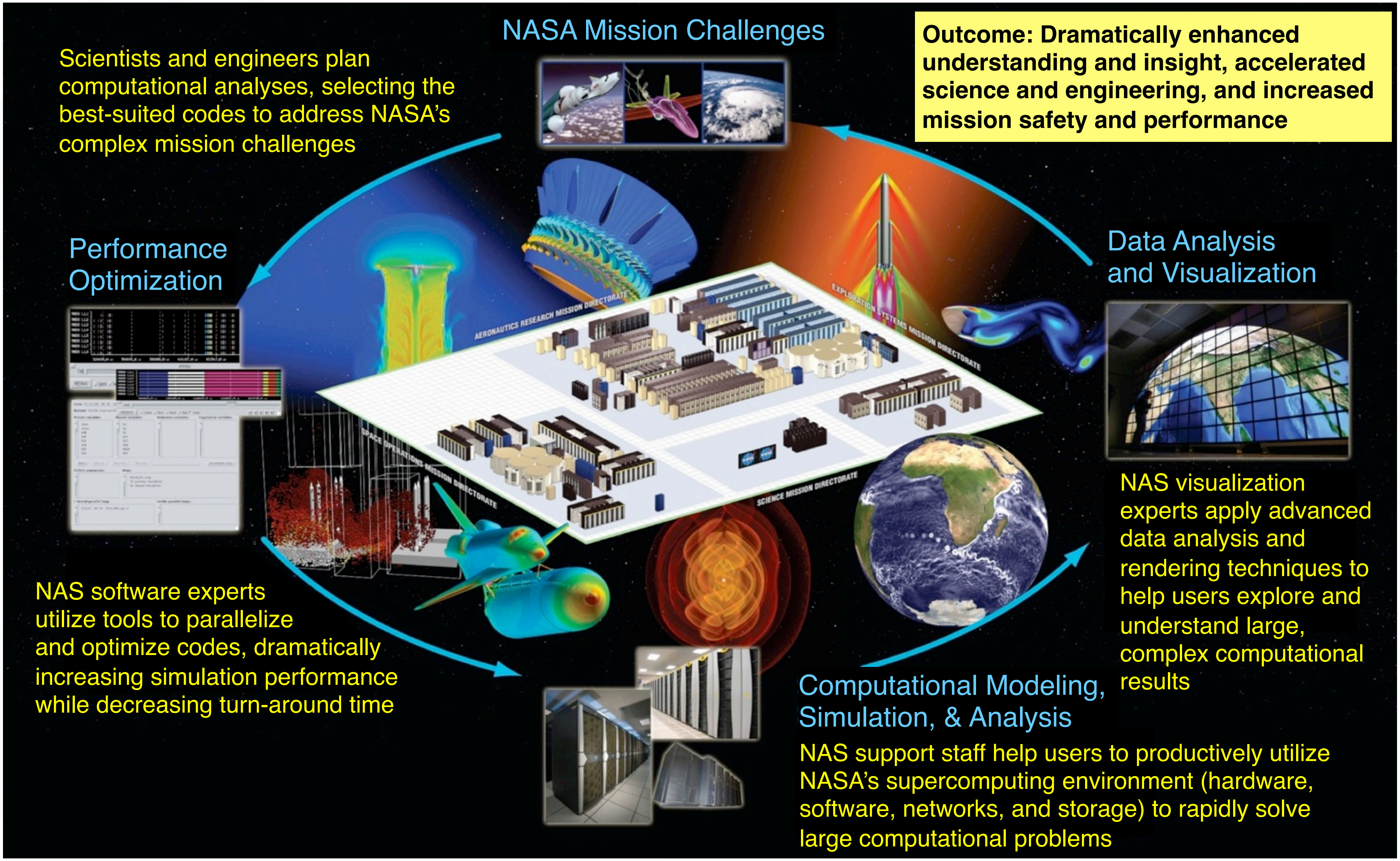


Space Shuttle debris transport analysis

3) Time-sensitive mission-critical applications require HEC resources on demand **(high availability / maintain readiness)**

Fully Integrated Spiral Support for Advanced Computational Modeling and Simulation

Develop and deliver the most productive high-end computing environment in the world, enabling NASA to extend technology, expand knowledge, and explore the universe



World-Class Supercomputing Capabilities: Enabling NASA Science and Engineering

Computing Systems

- Pleiades – 1.342 PetaFlops (PF) peak
  - 113,408-core SGI Altix ICE
  - 3 generations of Intel Xeon processors
  - 186 racks, 210 TeraBytes (TB) of memory
  - Debuted as #3 on TOP500 in 11/08; now #7
  - 2 of the racks contain 64 Nvidia M2090 GPUs (41 TF, 1.5 TB)
  - 24 more racks (575 TF peak) by early June
- Columbia – 29 TF peak
  - 4,608-processor SGI Altix (Itanium2)
  - Debuted as #2 on TOP500 in 11/04
- hyperwall-2 – 146 TF peak
  - 1,024-core (Opteron), 136-node GPU cluster
  - Large-scale rendering, concurrent visualization

Balanced Environment

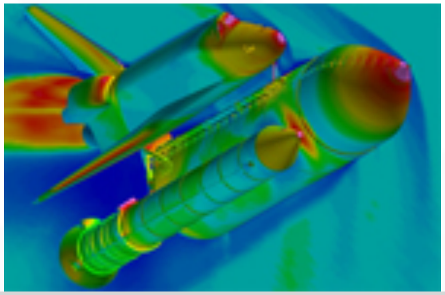
- Storage: 10 PetaBytes (PB) disk; 50 PB tape
  - Archiving ~1PB/month
  - Usage growth ~1.9X/yr since 2000
- WAN: 10 Gb/s to some Centers and high-bandwidth external peering
  - Transferring 150 TB/month to distributed users

- Resources enable broad mission impact
  - MDs select projects, determine allocations
  - More than 500 science & engineering projects
  - Over 1,200 user accounts
  - Typically 300 to 500 jobs running at any instant
  - Demand for computing cycles extremely high
  - ~90 million CPU-hours delivered each month
- HEC demand & resources growing rapidly
  - NASA HPC requirements projected to multiply by at least 4X every 3 years (Moore's Law)
  - Capacity growth ~1.8X/year since 1988

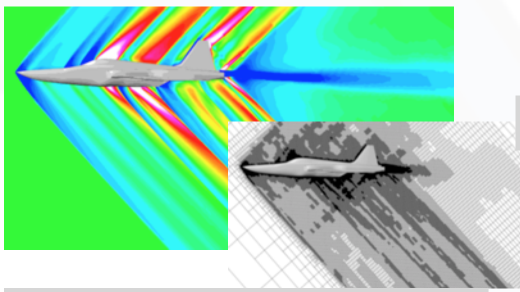
Advanced Visualization: hyperwall-2 and CV

- Supercomputer-scale visualization system to handle massive size of simulation results and increasing complexity of data analysis needs
  - 8x16 LCD tiled panel display (23 ft x 10 ft)
  - 245 million pixels
  - Debuted as #1 resolution system in world
  - In-depth data analysis and software
- Two primary modes
  - Single large high-definition image
  - Sets of related images (e.g., a parameter space of simulation results)
- High-bandwidth to HEC resources
  - *Concurrent Visualization:* Runtime data streaming allows visualization of every simulation timestep – ultimate insight into simulation code and results with no disk i/o
  - *Traditional Post-processing:* Direct read/ write access to Pleiades filesystems eliminates need for copying large datasets
- GPU-based computational acceleration R&D for appropriate NASA codes

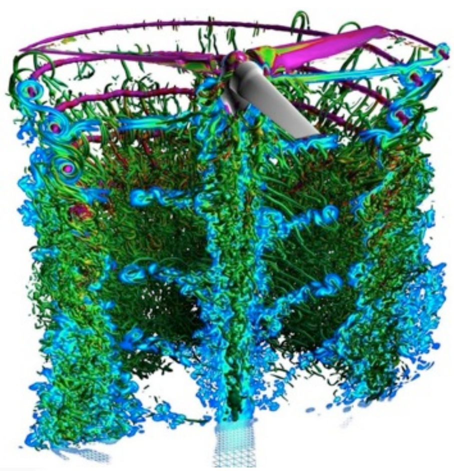
Strategic Support for all NASA MDs



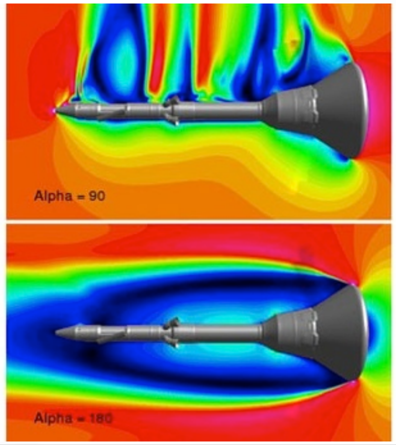
External tank redesign



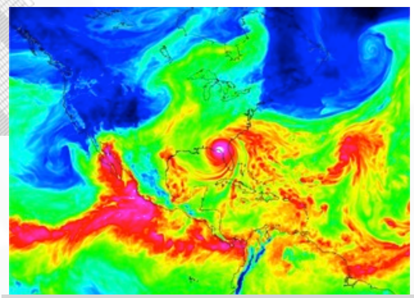
Sonic boom optimization



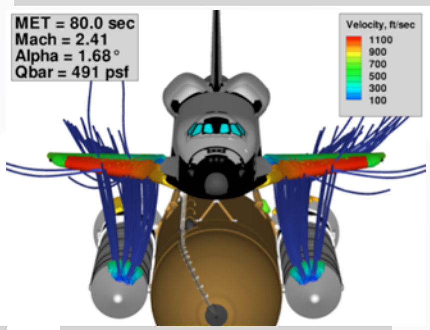
Rotary wing aerodynamics



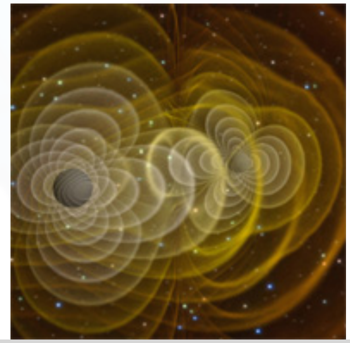
Launch abort system



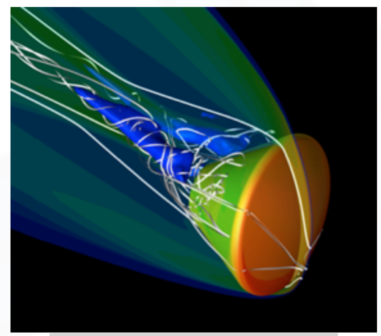
Hurricane prediction



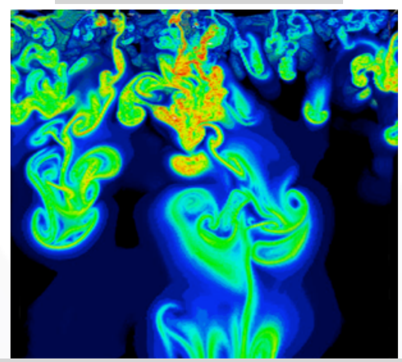
Debris transport



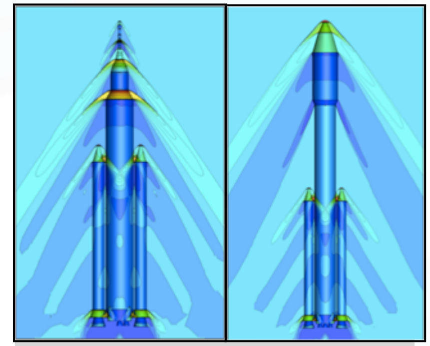
Merging black holes



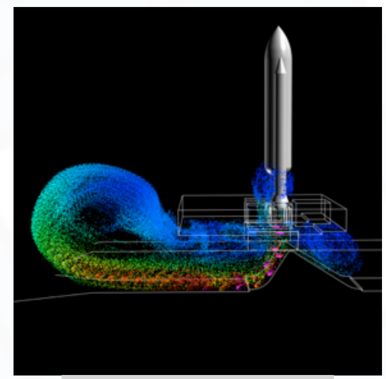
Orion reentry



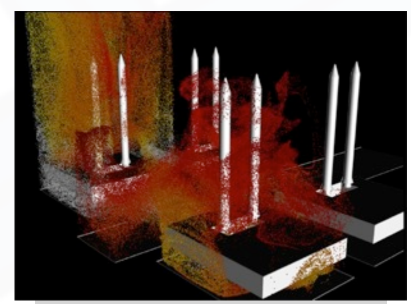
Solar magnetodynamics



SLS vehicle designs



Flame trench



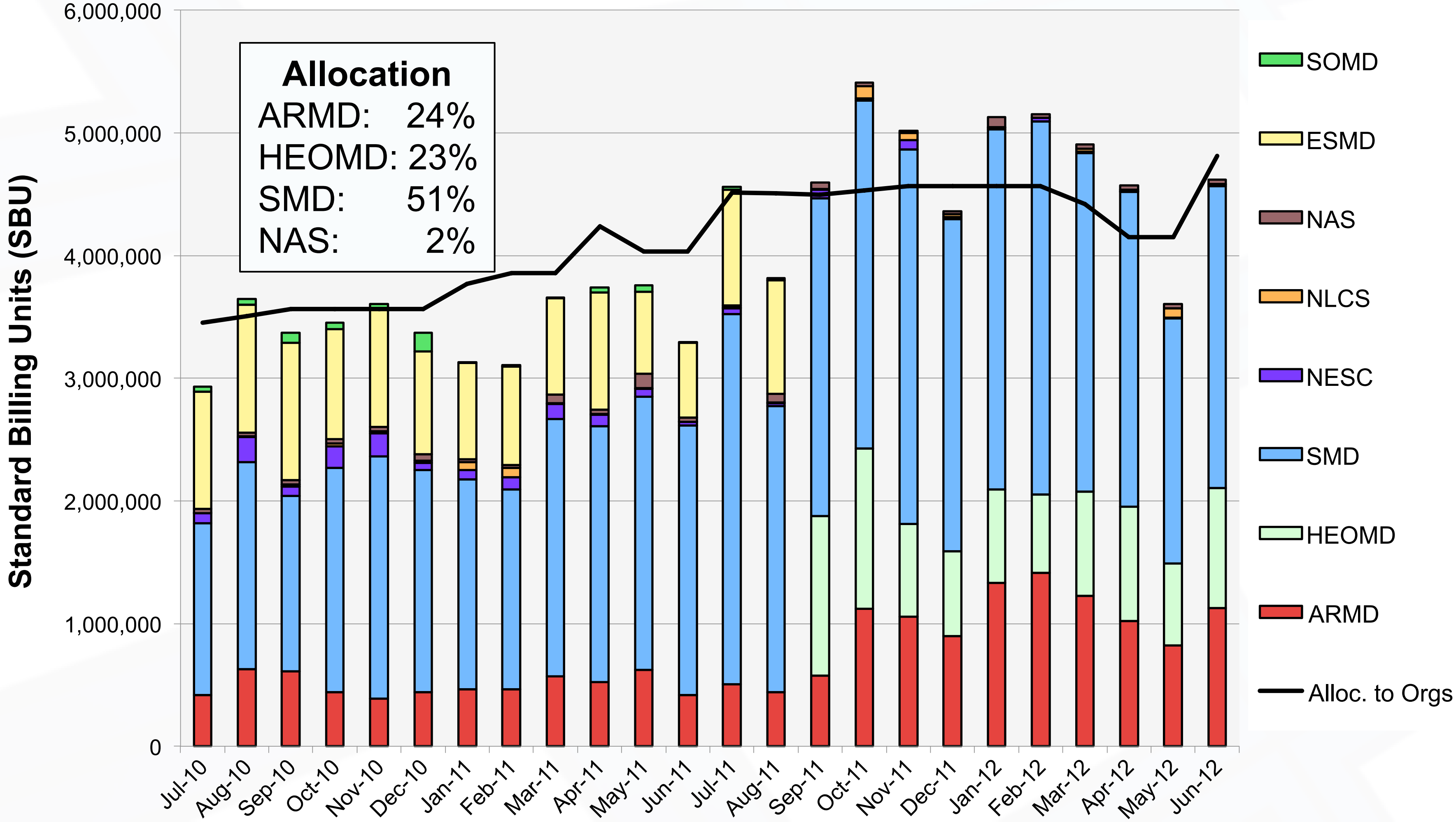
SRB burn in VAB

Driving Forces

Several NASA requirements against which emerging technological opportunities must be evaluated

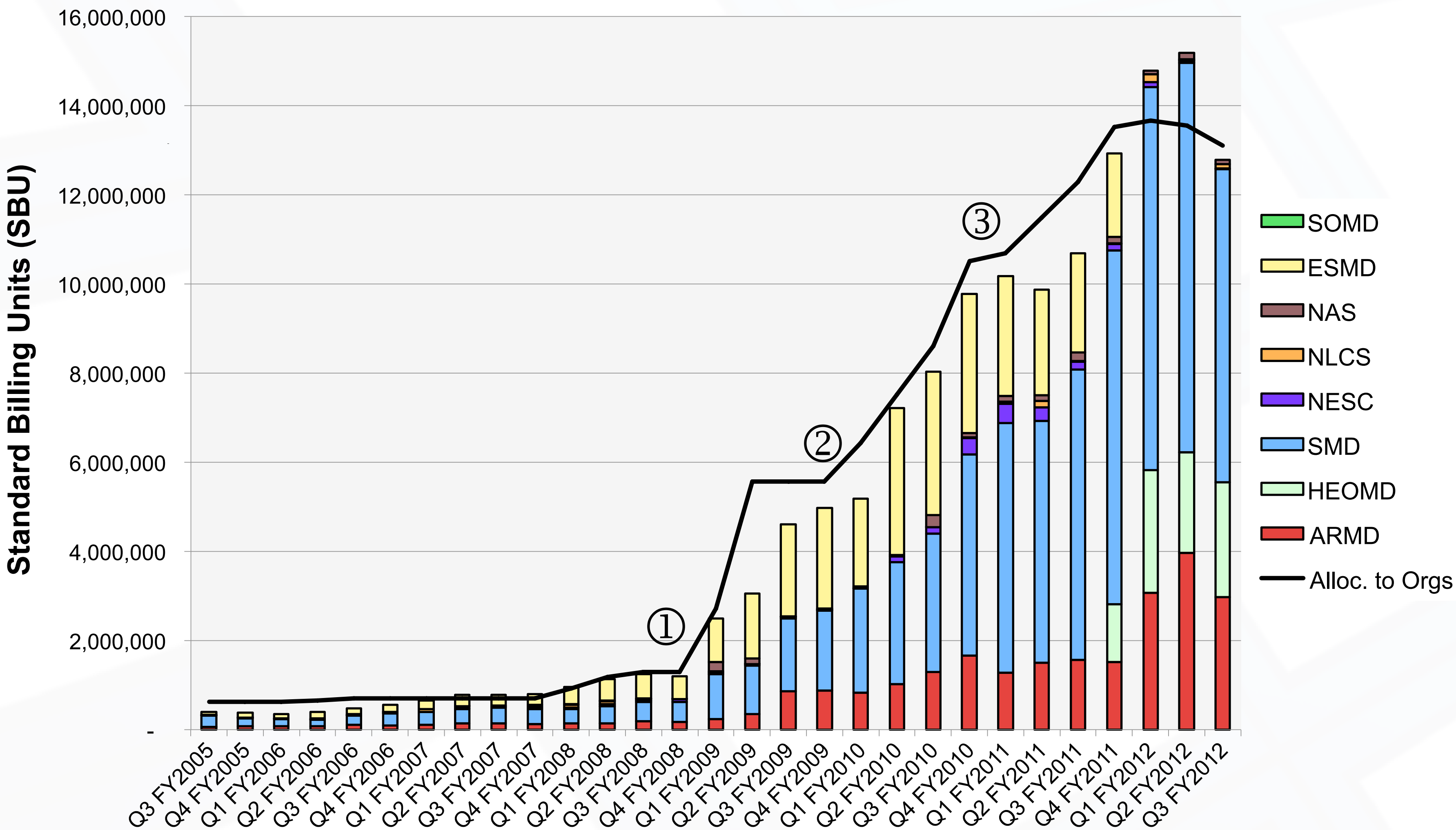
- Do more science within the same budget *("flat is the new high")*
- Grow production supercomputing capacity and capability to readily meet exponentially increasing user requirements
- Integrate new architectures and environments that better match NASA's important problem characteristics
- Assist diverse S&E user community to efficiently adopt and leverage new hardware and software technologies
- Improve data access bandwidth and latency to feed models and analysis
- Incorporate existing / Develop new tools to accelerate analysis of output data, its comparison to measurements, and extracting / capturing / disseminating knowledge
- Faster (near real-time) and more user-friendly data analysis and visualization

NAS Utilization Normalized to 30-Day Month



SBU: One Westmere node-hour (24 hyperthreaded core-hours)

Historical Utilization Over Past 7 Years



① Pleiades added ② SMD augmentation ③ Westmere processors added